# HIGH POWER REPETITIVE STACKED BLUMLEIN PULSE GENERATORS PRODUCING WAVEFORMS WITH PULSE DURATIONS EXCEEDING 500 N SEC

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## Abstract

The repetitive stacked Blumlein pulse power generators developed at the University of Texas at Dallas (UTD) consist of several triaxial Blumleins stacked in series at one end. The lines are charged in parallel and synchronously commuted with a single thyratron at the other end. The number of lines can be varied from 2 to 12 and in this way, relatively low charging voltages are multiplied to give a high discharge voltage across an arbitrary load without the need for Marx bank circuitry. In this report, performances of these Blumlein pulsers with different line configurations and extended line lengths are given. It is demonstrated that they are capable of producing switching waveforms with fast risetimes and with pulse durations exceeding 500 nsec without degradation of the voltage gains. The existing opportunities in tactically packaging these devices are discussed and demonstrated.

## Introduction

Construction and characterization of a laboratory scale pulse generator, driven by stacked Blumleins was reported by the UTD group in 1987 [1]. It had eight triaxial Blumleins stacked in series at one end. The lines were charged in parallel and synchronously switched with a single thyratron. Unlike the transmission line transformer (TLT) systems [2], the use of a single thyratron permitted operation of this Blumlein pulser to repetition rates in excess of 100 Hz. Scaling of this impulsive device to potentials exceeding 400 kV while retaining the capabilities for operation at high repetition rates was reported subsequently [3]. There a second prototype pulse x-ray generator, driven by stacked Blumleins was described. Improvements in the design and construction of this pulse power source resulted in voltage gains of six times the charging voltage of each line. An extensive characterization of the performance of this generator was given. It was noted that the maximum number of lines which can be stacked had not been reached. Scaling of this device to obtain voltages in excess of 0.5 MV was described recently [4,5]. It was applied to drive low impedance x-ray diodes giving high power x-ray pulses with duration as short as 20 nsec.

The use of a single switching element and the charged pulse forming lines are novel aspects of UTD stacked Blumlein pulse generators. Similar approaches with stacked TLT have been reported recently [6]. A four stage TLT was driven from four LC generators switched by a single thyratron. The pulser produced output voltages of 200 kV at 40 Hz of repetition rate. However, in addition to the thyratron, four magnetic switches had to be introduced to sharpen the pulses [6].

Our Blumlein pulse power sources have been mainly used to drive x-ray diode loads. Reasonable matching of diodes to the pulse generators have allowed for the production of high power x-ray pulses with duration as short as 20 nsec. Characterization of these flash x-ray systems have been given in detail elsewhere [1,3-4,7-8]. They have also been used to excite the fluorescence from high-pressure rare gas plasmas [9]. The deposition of hundreds of millirads of x-rays in nanosecond pulses into tens of atmospheres of argon gas has resulted in a strong excitation of the VUV spectra that depends upon the generation of lightly ionized precursors [9].

Recently, performances of stacked Blumlein pulsers with four and six Blumlein lines prior and after stacking the lines were characterized [10]. To gain better understanding of the pulsers, two different Blumlein configurations arbitrarily denoted A and B were used. For the pulser with configuration A, charging plates in each triaxial Blumlein terminated at 4.2 m from the thyratron, while in the B configuration, the charging plates were extended another 5 m to the stacking locations. In all cases, the current pulse conducted through the switching device was properly launched into each line and the Blumlein losses were found to be negligible. Operation of the devices in the B configuration increased the pulse duration of waveforms at the load by a significant amount without any degradation in the peak values or voltage gains. The adjustability of the waveform pulse widths indicated that by increasing the charged Blumlein lengths, waveforms pulse durations available from the device could be increased.

In this report performances of this novel pulser with line impedances of 25 Ω and 50 Ω and extended Blumlein lengths are given. The generations of waveforms with pulse durations in the range of 100 - 600 nsec are demonstrated. In order to produce a more compact device, the pulser is reconfigured with smaller spacings between the Blumlein planes and copper Blumleins were replaced with aluminum conductors.

## Design and Construction Review

Design and construction of these stacked Blumlein pulse generators were given elsewhere [1,3-5]. Briefly they consisted of three separate but integrated subassemblies: (1) the switching assembly, (2) pulse-forming Blumleins, and (3) the pulse-stacking module. Each of the sections may be removed and can be modified and/or serviced independently. The purpose of the switching assembly is to distribute the switching current to each of the Blumleins in a manner to avoid both transit time inequalities and path constrictions. The thyratron housing and current returns

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14. ABSTRACT
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were constructed in a way to reduce overall inductance of the switch circuit and to accommodate either 5.1 cm or 2.5 cm wide Blumlein copper conductors. The ground plates from each Blumlein were smoothly twisted 90° and were connected and welded to the thyratron cathode mounting ring. Charging copper lines were also constructed with a 90° twist and were welded to the current return plates at the thyratron end. These current returns were connected to the thyratron anode disc in a coaxial configuration to give a low profile geometry. The switching assembly was pressed together by grooved plexiglas and benelex plates and installed vertically as shown in Fig. 1. Each of the pulse forming Blumleins were composed of three copper plates with two 2.3 mm thick laminated polyimide insulators placed along the length between the copper conductors. These triaxial Blumleins were held together by delrin presses and switching sides were connected to the switching assembly as seen in Fig. 1.

The pulse forming lines were constructed from 3.7 m long sections of copper plate. They were 3.2 mm thick and 5.1 cm or 2.5 cm wide with rounded edges. The laminated Kapton sheets were 15.2 cm wide to prevent electrical breakdown between copper lines. Several of these sections were set on shelves and fabricated U-turns were used to connect them together. In this way several Blumleins were placed on the shelves, one above the other. At one end, these lines were connected to the vertical switching assembly. The charging plate in each Blumlein was extended to the close proximity of the stacking location through the U-turns. The Blumlein impedances of 25 Ω or 50 Ω were selected by using Kapton dielectric boards with similar thicknesses and copper conductor plates with widths of 5.1 cm or 2.5 cm, respectively. In both configurations copper foils were connected to the ground plates of the Blumleins and angled together along with the dielectric for another meter, where they were stacked directly on top of one another as shown in Fig. 1. The lines were connected in series for about 10 cm and the top and bottom copper leads connected to a load, across which the output of the pulser was measured. The lengths of the Blumleins could be adjusted to give the pulse duration of generated waveforms.

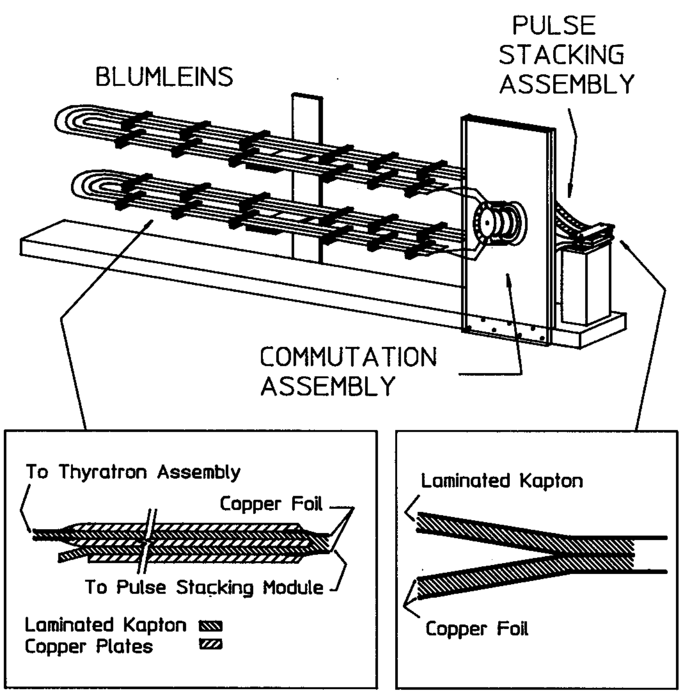



Figure 1. Schematic drawing of the 2-line stacked Blumlein pulser with a line length of 9.2 m. Cross section drawings of the pulse stacking module where the lines connect in series and each Blumlein with charging plates extending from the thyratron to the pulse stacking module are shown. The break includes a U-turn in each line.

## Device Performance

In this work, performances of 2-line stacked Blumlein pulse generator with blumlein lengths of 9.2 m and 48.2 m and line impedances of 25 Ω and 50 Ω were characterized. The full capacitance of the system was charged in 150 µs with a pulse-power supply [5]. Commutation was effected by a four-gap EEV CX 2025X Deuterium thyratron at repetition rates of 1-50 Hz. Voltage and current pulses were measured with a tapped, water resistor voltage divider and a fast current monitor, respectively. Outputs of these pulse measuring devices were connected to a Tektronix 7912AD transient digitizer.

In the resistive loading condition of operation, the output from the pulsers were connected to nominally matched loads built from a stack of five to ten, 10 Ω non-inductive carbon disc resistors. The output voltage waveforms were measured across the first carbon resistor in the load stack and then were multiplied by a factor of 5 and 10 for the pulsers with line impedances of 25 Ω and 50 Ω, respectively. The voltage waveforms for these resistive loading conditions of operation and Blumlein lengths of 9.2 m and 48.2 m are shown in Fig. 2. The voltage waveforms in this figure indicate voltage gains of about 1.8 and 1.9 for the pulsers with line impedances of 25 Ω and 50 Ω respectively.

A comparison of voltage waveforms obtained from the pulsers with nominal Blumlein lengths of 9.2 m and the pulsers with Blumlein lengths of 48.2 m, as seen in Fig. 2, indicates that for both pulser configurations with line impedances of 25 Ω and 50 Ω, the extension of Blumlein lengths resulted in generation of waveforms with pulse durations of about 500 ns longer without degradation in voltage gains.

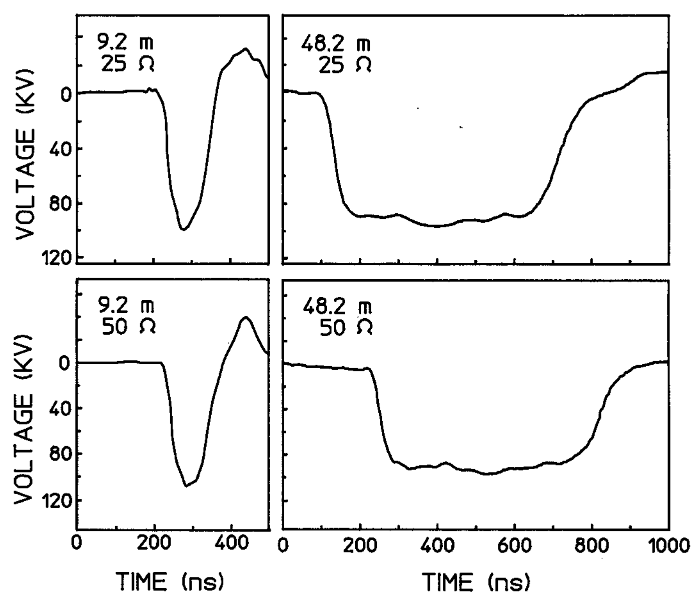



Figure 2. Resistive load voltage waveforms for the stacked 2-line pulsers with the Blumlein lengths of 9.2 m and 48.2 m and line impedances of 25 Ω and 50 Ω. These particular waveforms correspond to a charging voltage of 50 kV and resistive loading mode of operations.

### Device Packaging

It should be noted that the stacked Blumlein pulsers initially were developed to drive the flash x-ray diodes. These pulse x-ray systems and their supporting components were originally designed in a manner to accommodate 8 - 18 Blumleins to access a wide range of x-ray energies. The issues of ease of operation in the laboratory environment and versatility of the system outweighed the need for compactness and weight. However, for a particular application, the stacked Blumlein pulse generator can be developed into a tactical unit as is discussed in this section.

The weight and volume for the major sections of the 2-line pulser with Blumlein length of 48.2 m and line impedance of 50 Ω are given in Table 1. The performance of this pulser is described in the previous section. The opportunities for the reduction of weight and volume are evident from this table. For example, it is interesting to note that, although the pulser in the present configuration is occupying 1.92 $m^3$, the total materials volume does not exceed 0.34 $m^3$. Thus, the vertical and horizontal spacing of Blumleins may be reduced. However, the waveform characteristics must not be degraded.

To demonstrate the possibilities of developing the pulser into a light and compact device, the vertical between plane spacings of the Blumleins were reduced as shown in photographs of Figs. 3 and 4. The pulser was operated in both configurations and performances were characterized. No appreciable differences were identified between output waveforms generated by the device before and after reduction of Blumlein spacings. For example, current waveforms of Figs. 3 and 4 for resistive loads are identical. The reduction of Blumlein spacings brought down the occupying volume of the device from 1.92 $m^3$ to 1.27 $m^3$. It seems that the volume of device can be reduced further by placing the Blumleins closer to each other.

In this work Blumlein copper conductors of the pulser in the configuration of Fig. 4 were replaced by similar size aluminum conductors. Again, the operation of the pulser showed no degradation of the generated waveforms. A comparison of the current pulses for resistive loads shown in Fig. 3, 4 and 5 indicates no change in waveform characteristics. The choice of aluminum conductor offers a weight reduction for the pulser of 146 Kg. As seen in Table 1, considerable portions of the weight and volume of the pulser belong to the support structures which could be also reduced by avoiding heavy materials in their construction.

### Conclusions

Characterization studies of the stacked Blumlein pulse generator using 2 Blumleins have been performed for different line impedances. The pulsers are capable of producing high power pulses with durations of about 600 nsec. The results obtained

TABLE 1

WEIGHT AND VOLUME FOR THE 2-LINE STACKED PULSER WITH LINE IMPEDANCE OF 50 Ω

| Pulser Major Sections* | Sub-Assembly Components | Weight (kg) | Volume ($cm^3$) |
|---|---|---|---|
| Blumleins | Copper Conductors | 210 | 23793 |
| | Laminated Kapton Dielectric | 94 | 77591 |
| | Delrin Line Press System | 73 | 51913 |
| Switching Assembly | Thyratron and its Current Returns | 8.1 | 2800 |
| | Supporting Structure | 33 | 25763 |
| Pulser Support and Lift System | Delrin Shelves | 56 | 46397 |
| | Aluminum Bars | 123 | 44992 |
| | Misc Items | 172 | 59519 |
| | Totals: | 769 kg | 0.333 $m^3$ |

* Major sections do not include tank, transformer oil and pulse charging supply.

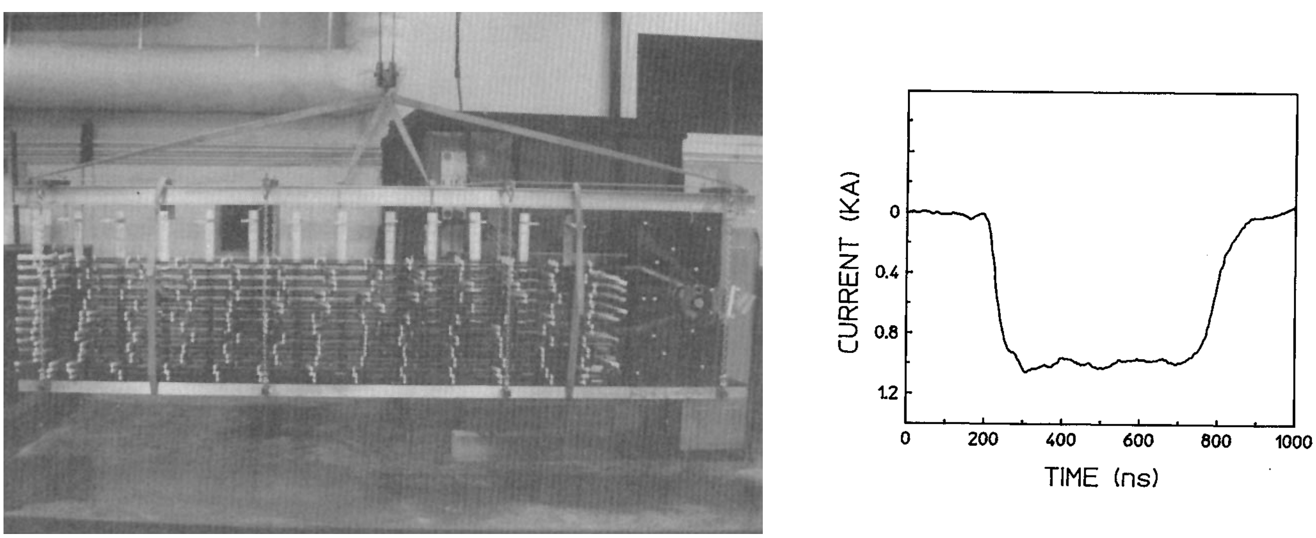
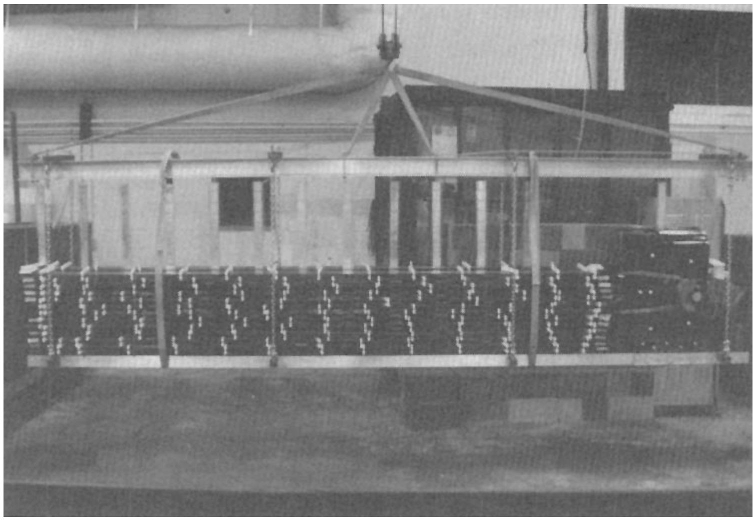



Figure 3. (left) Photograph of the 2-line stacked pulser with the line length of 48.2 m and line impedance of 50 Ω before reduction of Blumlein spacings. (right) Resistive load current waveform obtained from the pulser. This particular waveform corresponds to a charging voltage of 50 kV.



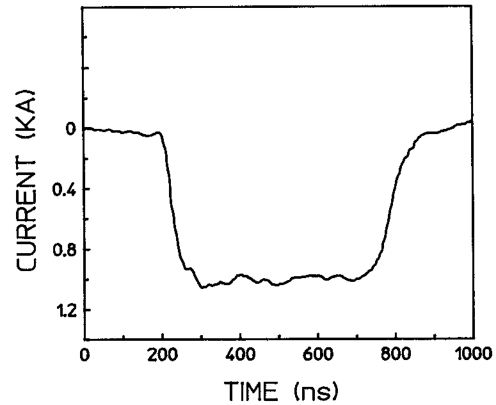




Figure 4. (left) Photograph of the 2-line stacked pulser with the line length of 48.2 m and line impedance of 50 Ω after reduction of Blumlein spacings. (right) Resistive load current waveform obtained from the pulser. This particular waveform corresponds to a charging voltage of 50 kV.

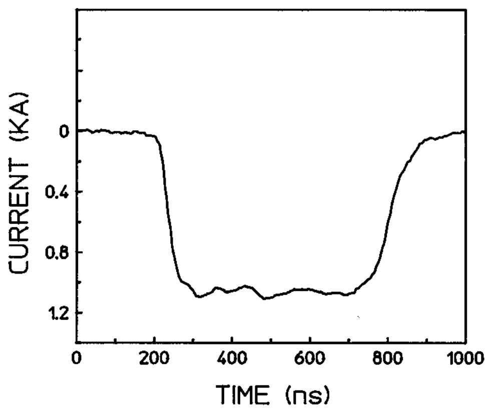




Figure 5. Resistive load current waveform obtained from the 2-line stacked pulser with aluminum conductors after reduction of Blumlein spacings. Pulser has the line length of 48.2 m and line impedance of 50 Ω. This particular waveform corresponds to a charging voltage of 50 kV.

in this work demonstrate the versatility of these devices for use in different pulse power applications. With slight modification they can produce waveforms with fast risetimes and a wide range of pulse durations and peak values. It is shown that the stacked Blumlein pulsers can be developed into light and compact devices without degradation in their performances.

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